TABLE 31.—*Average hourly relative humidity at Colon, Canal Zone.*

(5-7 years.)

Hours.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
2a	83	82	80	83	88	91	90	91	92	93	92	88	88
4a	83	83	81	84	89	92	91	91	92	93	92	88	88
6a	84	83	81	84	89	92	91	91	92	93	92	88	88
8a	83	83	81	83	88	91	90	91	91	91	91	88	88
10a	80	80	76	79	84	87	86	86	85	84	86	85	83
Noon	76	76	73	75	81	81	83	82	80	78	83	82	79
2p	*75*	*75*	*72*	*75*	*81*	*80*	*81*	*82*	*77*	80	*83*	*80*	*78*
4p	75	75	73	75	82	82	83	84	82	83	84	81	80
6p	78	77	75	77	83	84	85	85	84	86	87	83	82
8p	81	80	78	80	86	87	87	87	87	89	88	85	85
10p	82	81	80	82	87	88	88	89	89	91	90	86	86
12p	83	82	80	82	88	90	90	90	91	91	91	87	87
Mean	80	80	77	80	85	87	87	87	87	88	88	85	84

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THE FUNCTION OF THE ATMOSPHERE IN [WIRELESS] TRANSMISSION.[1]

By J. ERSKINE-MURRAY, Sc. D.

[Dr. James Erskine-Murray was born in Edinburgh on October 24, 1868, and after a course of six years' study under the late Lord Kelvin at Glasgow University he entered Trinity College, Cambridge, as a research student. In 1898 he was appointed experimental assistant to Mr. Marconi. In 1900 he took up the post of lecturer and demonstrator in physics and electrical engineering at the University College, Nottingham, and in 1905 he was appointed to the lectureship in electrical engineering at the George Coates' Technical College, Paisley. In 1905 he took up consulting work in radiotelegraphy.

[The following paper is reprinted by permission of the editor of the Yearbook, Mr. Arthur Cohen.]

An interesting article by Dr. Eccles on certain aspects of transmission through the atmosphere appeared in the Yearbook [of wireless telegraphy] for 1913, the treatment of the subject being mainly from the point of view of his own and other physical theories for the explanation of "freak" transmissions. In the following pages I have attempted to analyze typical cases of unusual wireless transmission and to deduce from these in conjunction with the known and fundamental physical facts of the case a true idea of the function of the atmosphere in transmission without the use of any explanatory hypotheses.

That the atmosphere ought to have some slight influence on the transmission of electric or "ether" waves from place to place on the earth's surface is obvious when one recollects that the air, though a very good insulator at pressures such as exist at the earth's surface, is nowhere a perfect insulator and has quite different electrical qualities at the low pressures which occur at heights above 30 or 40 miles to those it possesses at lower elevations.

Electrical waves must necessarily have a good insulator to pass through; they are guided by a conductor, but do not pass through it, only diffusing slowly into it and being dissipated as heat in the conducting material. The better the conductor the smaller is the depth of penetration of the waves into it and the less the loss of energy on this account. At the same time every conductor, whether a wire or a great mass like the earth, does conduct—that is to say, the electrical disturbance follows and is guided by its surface.

In Hertz's experiments and in Mr. Marconi's earliest form of apparatus true radiation took place, i. e., there was a free and unguided passage of an electric disturbance from one conductor to another conductor through an insulating medium, the air, in which both were situated.

In modern wireless telegraphy free radiation does not take place when the stations are situated on land or sea, for the receiver is actually in direct connection with the earth and the latter forms part of the transmitter. Modern wireless is thus merely transmission from one part of a conductor to another part of the same. No return circuit such as is used in ordinary telegraphy is needed, because the disturbance is not continuous but alternating, and is of comparatively small wave length. I may quote from the 1907 edition of my handbook[2] a definition which puts the matter succinctly; it is as follows:

> Reduced to its simplest terms, the modern wireless telegraph is a large conducting sphere (the earth) with two conducting excrescences on it or near its surface (the aerial conductors). In one of these a sudden oscillatory movement of electricity is started, which spreads over the surface, causing to-and-fro currents in the other wire is it passes.

It will be understood, therefore, that as these have been my views since 1898, I was not one of those whom Dr. Eccles in his article in last year's Yearbook speaks of as being surprised at Mr. Marconi's success in trans-Atlantic transmission round the curve of the world.

If the lower atmosphere were as conductive as the sea is, wireless telegraphy from place to place on the earth's surface would be impossible, for the electric waves would not penetrate such a material to more than a few yards from the transmitter. Thus wireless telegraphy between completely submerged submarines is impracticable. The same is true in regard to wireless transmission in mines. Where the rocks are dry and insulating, transmission is possible through them up to a mile or two; but where they are wet and therefore conducting, wireless telegraphy is impracticable. The nonconducting layer of air in contact with the ground and rising to some 30 miles above it is thus the stratum through which the electric waves can pass in traveling from station to station. Above lies the less dense air which is certainly not a good insulator and therefore must either absorb or reflect the waves which come up to it from the transmitter. There is now experimental evidence that at night this upper layer does reflect the waves down again, and thus signals are received at greater distances than in the daytime; and Dr. [L. W.] Austin is of opinion that even in the daytime the action is not always absorption only, but that occasionally there is a slight strengthening of the signals by reflection.

The first suggestion of which I am aware, that indicates the importance of the upper atmosphere in the transmission of electrical waves over the earth's surface is contained in a paper which the late G. F. Fitzgerald read at the British Association Meeting in 1893. In discussing the probable period of an electrical oscillation of the earth as a whole, he remarks that—

> The period of oscillation of a simple sphere of the size of the earth, supposed charged with opposite charges of electricity at its ends, would be almost one-seventeenth of a second; but the hypothesis that the earth is a conducting body surrounded by a nonconductor is not in accordance with the fact. Probably the upper regions of our atmosphere are fairly good conductors.

He then proceeds to calculate the period of oscillation considering the earth and upper atmosphere as two concentric spherical conductors and finds that if the height of the region of the aurora, i. e., of the conducting layer, be 60 miles the period comes out at 0.1 second, while, if the height be 6 miles, the period becomes 0.3 second.

[1] *Reprinted by request from* Year Book of Wireless Telegraphy and Telephony, 1914. Marconi Press Agency (Ltd.), London, [1914]. p. 504-512.

[2] Erskine-Murray, J. Handbook of wireless telegraphy. London, 1907.

At the time this was written wireless telegraphy, in the modern sense, had hardly been thought of, and no application of Fitzgerald's idea was made to radiotelegraphy until 1902, when A. E. Kennelly[3], in the Electrical World, suggested that an upper reflecting layer might be the cause of the abnormally long ranges occasionally obtained by night. Oliver Heaviside also, in his article "Theory of electrical telegraphy" (Encyclopaedia Britannica, 10th edition), says:

> There may possibly be a sufficiently conducting layer in the upper air. If so, then waves will, so to speak, catch on to it more or less. Then the guidance will be by the sea on one side and the upper layer on the other.

It is clear, therefore, that in the opinion of Fitzgerald the upper conducting air actually existed, and that Kennelly and Heaviside looked upon its existence as probable.

The diagram (fig. 1), which forms an illustration to the chapter on transmission in the first and succeeding editions of the writer's Handbook of Wireless Telegraphy[2], published at the commencement of 1907, was arrived at from similar considerations in combination with the known facts of the conductivity of gases at low pressures, of the height of the auroral discharge and of the constant presence of ionization in the upper atmosphere. It was

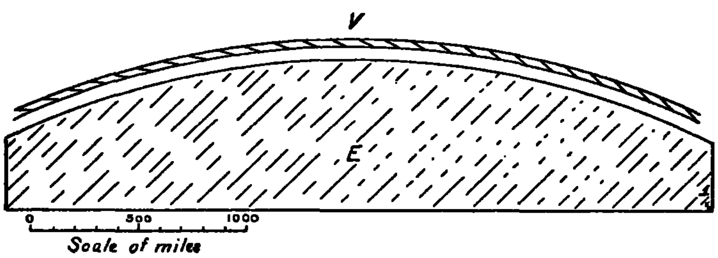

FIG. 1.—A portion of the earth and atmosphere drawn to scale. *E*, the earth; *V*, outer space. Shaded portions indicate conductors, the unshaded strip between them is the dielectric of wireless telegraphy. (*From* Erskine-Murray, Handbook of Wireless Telegraphy, 1907.)

thus an immediate deduction from the knowledge available at the time.

As regards the ionization of the upper atmosphere, I may say that as early as 1892 I wrote a paper in which a calculation was made of the currents in the upper atmosphere which would be necessary to account for certain magnetic storms and suggested that these currents might be due to streams of electrified particles entering the atmosphere from the outside. A great deal of work on similar lines has been done lately by Birkeland. That ordinary sunshine containing ultra-violet light ionizes air was well known, as also the fact that ionization does not die out at once.

The diagram (fig. 1) indicates that if the under surface of the upper conducting layer were sufficiently sharply defined, the waves would be reflected downwards and might, therefore, increase the strength of signals received, the wave form becoming ultimately—i. e., at great distances—cylindrical instead of hemispherical, and therefore giving a much slower reduction in the strength of received signals than would occur if the waves were free to extend into upper space or were absorbed by and dissipated in the upper layers. I consider that the existence of this upper conductive layer is no longer a matter of doubt, and that the problems now in the process of solution involve only its form and functions. To be able to discuss these we must leave for the meantime the physical side of the question and look into the evidence obtained in the actual working of wireless telegraph stations.

The first time that an obviously atmospheric effect was noticed was in 1902, when Mr. Marconi received signals from Poldhu on board the steamship *Philadelphia* at nearly twice as great a distance by night as by day.

Since the conductivity of the surface of the sea is not appreciably different by day and by night, it is evident that the cause of this increase of distance of transmission at night must be some atmospheric variation. Mr. Marconi suggested that at the time the effect might be a local one, i. e., a loss of energy at the transmitting aerial due to ionization by daylight of the air in its immediate neighborhood. This theory, however, does not fit in with the more recent observations of the phenomena, which clearly indicate that the cause is situated in the atmosphere intervening between the stations and is not due to variations in the amount of energy radiated.

Take, for instance, Edward's observations on transmission by day and by night on the coast of British Columbia, and in particular the case of communications between Victoria, Pachena Point, and Ikeda Head. These three stations lie in nearly a straight line, Pachena Point being about 75 miles and Ikeda Head about 400 miles northwest of Victoria. Electric waves in transmission from Victoria to Ikeda Head thus pass Pachena, and if they traveled by the shortest route, i. e., along the earth's surface, should be received there.

As a matter of fact, however, with the small power station originally installed, it was very difficult to communicate between Victoria and Pachena at all, either by day or night, whereas communication was easily maintained between Victoria and Ikeda Head almost every night, though not by day.

There appears to be only one rational conclusion which can be drawn from these observations, viz, that at night the waves which reached Ikeda Head actually passed Pachena high overhead without approaching the ground on which the station stands; that is to say, they rise from Victoria and are bent down again after they have passed over Pachena Point. There is no other way by which they could get to Ikeda Head without affecting the intermediate station. We have thus a direct proof from actual wireless operations that there must be some stratum of the upper atmosphere which, at least by night, is not transparent to electric waves but reflects or refracts them downward from its lower surface.

From the consideration of the physics of the atmosphere and from actual wireless observations, we have thus obtained two quite independent proofs of the existence of the upper conducting layer depicted in figure 1.

The above are, of course, only instances taken from a very large number of observations, all of which go to prove the existence of a strengthening of signals due to reflection from the upper atmosphere. These "freak" transmissions occur in all latitudes, but mainly in the fine-weather belts which surround the world between latitudes 20° and 45° on both sides of the Equator. It is also there that the atmosphere is, as we know from the work of meteorologists, in a comparatively steady condition such as must favor the formation of a smooth reflecting layer. There is also evidence which shows that stormy weather is unfavorable to transmission.

It is notable that many of the greatest distances of "freak" transmission have been in large part over land, and indeed over high mountains—further proof that in these cases the main conductor is not the earth but the upper shell.

It is also a fact that signals between stations at a comparatively small distance from one another are not appreciably strengthened at night, and this further confirms

[3] *See also* A. H. Taylor in this REVIEW, April 1914, 42: 211, ffg.—Editor.

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the idea that the increase at greater distances is due to reflection. In the case, for instance, of Victoria and Pachena Point the angle at which the waves would have to be reflected from the upper layer is about 45° or more in order to reach the latter station. So high an angle is, of course, very unfavorable to reflection and a very small proportion, if any, of the waves received at Pachena Point could come that way. For Ikeda Head the angle would only be about 10°, which is very much more favorable; hence, as the phenomenon of better night transmission is observed at the latter, reflection is indicated. (See fig. 2.)

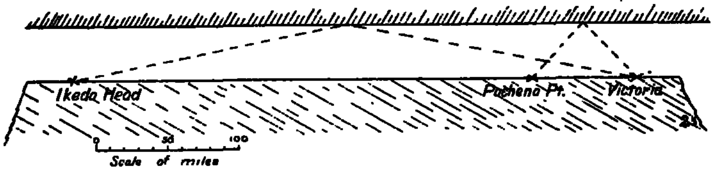

FIG. 2.—A portion of the earth and atmosphere between Victoria and Ikeda Head. *A*, Victoria; *B*, Pachena Point; *C*, Ikeda Head.

We may take it, therefore, that it is practically certain that during the night the waves are conducted to great distances by two conducting surfaces, the earth and the shell outside it. The argument put forward by Dr. Eccles against conductive transmission, viz, that a high receiving aerial is better than a low one, is really fallacious and neglects Poynting's proof that in all electrical transmission the energy travels via the dielectric and not in the conductor. Of course, a higher aerial will show greater energy in the receiving instruments in any case, for the integral effect of the electromagnetic forces on it will be greater than that in a small one, whether the waves be conducted or free. I have demonstrated this many times in lecturing on the subject by using a long horizontal straight wire to represent the conducting strip of ground between the transmitting and receiving stations, with two vertical wires attached to it as aerials.

It seems, therefore, that at night the lower surface of the conducting shell is often well defined, thus becoming a good reflector, while during the day the transition from the upper and conducting to the lower and nonconducting air is gradual—the surface, in fact, becomes fuzzy and incapable of giving a clear reflection.

We now come to the curious phenomena which take place at sunrise and sunset. Let us see what function the atmosphere performs in these, after stating generally the results which have been deduced from Mr. Marconi's interesting observations at Clifden and Glace Bay and from those of later workers.

In a paper on the "Daylight Effect in Radiotelegraphy," read to the Institute of Radio Engineers in July, 1913, Prof. A. E. Kennelly sums up the experimental facts and shows, as he says in his summary, that "changes of intensity of signals near sunrise and sunset are explained by reflecting effects which may be expected at the boundary surface or 'shadow wall' between darkness (air of small conductivity) and illumination (ionized air of marked conductivity)."

This is good if it applies only to the middle atmosphere below the layer, which, as we have seen, must be a good conductor even at night and above the lower layers, which under no conditions ever become appreciably conductive; but it neglects the fact that there are also long night ranges to be explained which demand something essentially better than merely a nonconducting atmosphere.

The real effect is, therefore, something like that shown in figure 3, a figure which I have frequently drawn on the blackboard for the benefit of a class during the past six years.

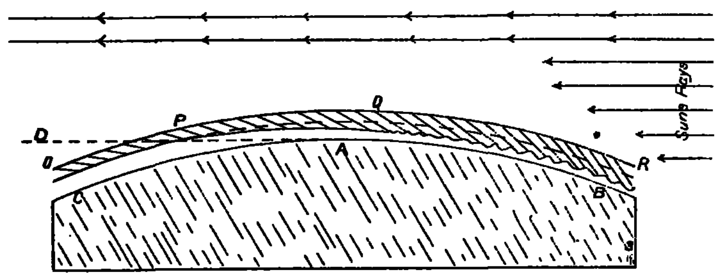

FIG. 3.—Illustrating the effect of the sun's rays on wireless transmission. *CAB*, the earth; *OPQR*, the conducting shell; *AD*, line dividing sunshine above from darkness below; *A*, station where the sun is just rising.

I have indicated that over the station *A*, at which sunrise is just taking place, the conducting shell is at least as sharply defined as during the night, and is therefore capable of reflecting; while at *B*, where the sun is high, the under surface of the shell is indefinite and no longer reflects. Between *P* and *Q* the shell slants downward toward the earth, forming what Kennelly calls the "shadow wall." It therefore strengthens forward radiation or condenses the received waves at *A*. Between *O* and *P* the shell is horizontal, as also between *Q* and *R*.

In order to follow the variations which sunrise produces in the strength of received signals it is necessary to suppose that the earth, represented by the lower part of the diagram, rotates slowly clockwise. The stations will then pass from where, in darkness, the height of the shell is great to where, in full daylight, it becomes lower and less well defined; and in their passage their positions relative to the shell will indicate the variations in signals.

To study the sunset effect we may turn the earth counterclockwise, starting with both stations in full daylight, i. e. on the right, and turning them gradually over into darkness. The point of view will in this case be from above the North Pole, while in the use of the diagram to illustrate sunrise it was from above the South Pole.

As Dr. Kennelly points out, the boundary between light and darkness is a line which is only due north and south at the times of the equinoxes. At other times of the year it has a northerly and easterly, or northerly and westerly slant, according to the season of the year. This boundary line is in fact a great circle of the globe, the axis of which is always directed toward the sun and therefore cuts the surface of the globe at some point on the ecliptic. Sunrise and sunset effects, therefore, vary from month to month, and depend not only on the times of sunrise and sunset, but also on the angle between the fixed great circle along which transmission takes place from the one station to the other and the great circle separating day from night.

In conclusion, I would suggest that there is another factor in the case of which no account has hitherto been taken. This is the possibility that there may be resonance to some of the natural wave lengths of the oscillator, consisting of the earth and the shell. These wave lengths are many in number and include a range of waves of lengths h, $2h/3$, $2h/4$, etc., where h is the distance between the earth and the shell. Thus, if the height of the shell be 50 kilometers, these natural wave lengths would be 50 kilometers, 33.3 kilometers, 25 kilometers, and so on: while if the height were different the whole series would be different. We have here, therefore, another possible explanation of the fact that both with damped and undamped waves it has been observed that at certain times certain wave lengths are more easily transmitted than others. I would suggest that, although this may be due to interference of direct and reflected waves, it may also be due in part at least to a change in the height of the shell, whereby the natural resonance wave lengths of the terrestrial oscillator are altered.

RAINFALL AFTER BATTLE.[1]

By GEN. H. M. CHITTENDEN, U. S. ARMY.

[Dated Port of Seattle, Seattle, Wash., October, 1914.]

To the Editor: I noted in the Post-Intelligencer [of Seattle, Wash.] an extract from Pearson's Weekly (London) in regard to the effect of battles in producing rain. There seems to be an almost universal belief in a direct relation between these two phenomena. Several years ago, in preparing a paper on the influence of forests on streamflow, I had a great deal of correspondence with Col. T. P. Roberts, of Pittsburgh, a brother, I believe, of Prof. Milnor Roberts, of our university [University of Washington, Seattle]. Col. Roberts called to my attention the fact that this belief in the effect of battles was prevalent in the days of the Roman Empire, and cited a paragraph from Plutarch to that effect. The matter seemed so interesting to me that I inserted it in the form of the following footnote in my paper:

Though admittedly irrelevant, the interesting character of the following item justifies its insertion here, as another example of the old saying that "there is nothing new under the sun." Everyone is familiar with the superstition (possibly it deserves a better name) that great battles produce rain. The vibrating effect upon the atmosphere of the multitudinous detonations of artillery is generally ascribed as the cause. Read this from Plutarch, who flourished 45-125 A. D.: "It is an observation also that extraordinary rains pretty generally fall after great battles; whether it be that some divine power thus washes and cleanses the polluted earth with showers from above, or that moisture and heavy evaporation, steaming forth from the blood and corruption, thickens the air, which naturally is subject to alterations from the smallest causes."

The fact that this belief is thousands of years old and antedates by at least a thousand years those physical causes (artillery bombardments) which are now the explanation assigned to this assumed relation, demonstrates how uncertain the relation itself is. The recent occurrences in France furnish no proof of the theory. There have been considerable spells of both fair and rainy weather, though conditions as to artillery practice were practically the same. On the basis of actual demonstration, therefore, it must be admitted that the theory does not have much to stand on.

Even if it were an established fact that heavy detonations or bombardments tend to condense the moisture of the atmosphere and cause precipitation, its value in a practical way would still be very questionable. When the atmosphere is well charged with moisture, natural causes lead to its condensation to an extent which probably satisfies the average need for it. Artificial rainmaking is not required at such times, but only in seasons of drought, when Nature's efforts in that direction seem to be suspended. But the power to produce rain at such times, even admitting its efficacy at others, fails because there is nothing to make rain of. No matter how efficient the pump, one can not pump water when the well is dry. So we are thrown back upon the greater problem of getting an atmosphere laden with moisture, and over this matter man has no more control than he has in restraining a surcharged atmosphere from spilling its moisture too rapidly and causing great floods.

[1] Published in the Seattle Post-Intelligencer of Oct. 5, 1914, and later revised by the author for the MONTHLY WEATHER REVIEW.

THE HOURLY FREQUENCY OF PRECIPITATION AT NEW ORLEANS, LA.

By EDWARD D. COBERLY, Local Forecaster.

[Dated Weather Bureau, New Orleans, La., Sept. 1, 1914.]

While the precipitation at New Orleans during the greater portion of the year perhaps does not differ materially, either in amount or in frequency of occurrence, from that at other stations along the Gulf coast from Florida to Texas, the rainfall during the months of June to September, inclusive, does possess certain characteristics which distinguish it very distinctly from that of other localities in the area mentioned. With a view to bringing out these peculiar characteristics of the summer precipitation at New Orleans, a study of the hourly amounts of precipitation and also the frequency of the precipitation during the different hours was undertaken, covering the period for which the hourly records are available at New Orleans, namely, 1905 to 1913, inclusive. The data collected in this connection have been summarized in a table which shows the number of times during each hour, for the entire period covered, that precipitation of 0.01 inch or more occurred, and in four charts showing graphically the diurnal march of the frequency of the precipitation for each month of the year.

As a glance at the chart (fig. 1) will show, from October to May, inclusive, the precipitation is very evenly distributed throughout the 24 hours, there being no marked excess in the number of showers at any particular period of the day. In June, however, and extending through September, the tropical characteristics of the rainfall become very marked, and 60 per cent of all the hours with rainfall occur from 10 a. m. to 6 p. m. and 40 per cent between the hours of 12 noon and 4 p. m. The greater portion of this summer rainfall occurs as the accompaniment of local thundershowers, which are recorded on an average of nearly half the days during the four months June to September, being most frequent in July and least frequent in September. The distribution of barometric pressure most favorable to these daytime thundershowers is an area of high pressure centered on the south Atlantic coast and gradually diminishing in intensity westward toward Texas. The frequent occurrence of these convectional rains in southeastern Louisiana, and especially in New Orleans and its immediate vicinity, is no doubt materially increased by the topographical surroundings of the city. It is almost entirely surrounded by water, thus giving to its summer climate a great many of the characteristics of a semitropical island, that is, clear weather during the night and early morning hours, rapidly increasing cumulus clouds during the forenoon, culminating in showers during the warmest hours of the day, together with an absence of great extremes of temperature.

The hour of greatest precipitation appears to become progressively later in the afternoon as the season advances, the period of most frequent rainfall in June being 1 p. m. to 4 p. m., there being not much variation in any of the afternoon hours; in July it is 1 p. m.; in August, 2 p. m.; and in September, 3 p. m.